

CR-170884

TECHNICAL NOTE

LOCKHEED

Huntsville Research & Engineering Center

SQT

Contract NAS8-32982 **Date** 13 July 1979 **Doc.** LMSC-HREC TN D697613

Title: SPACE SHUTTLE SRB TPS PROTECTIVE PAINT TEST AND EVALUATION
IN NASA HOT GAS FACILITY AND AEDC TUNNEL C

FOREWORD

This report documents the results and outcome of thermal tests conducted to evaluate the performance of the protective coat of paint on the SRB thermal protection system. Tests were conducted in AEDC Tunnel C and NASA Hot Gas Facility. AEDC/ARO and NASA-MSFC personnel conducted the tests while Lockheed-Huntsville personnel provided on-site monitoring and data evaluation.

Lockheed support was provided under Contract NAS8-32982, "Thermal Protection System for Solid Rocket Booster (SRB)." The NASA-MSFC Contracting Officer's Representative for this contract is Bill Baker, EP44. The AEDC/ARO Test Engineer was J. Ievalts; the NASA-MSFC Test Engineer was R. L. Stone, ET18; and Lockheed-Huntsville Test Engineer was Z. S. Karu.

Acknowledgment is given to AEDC/ARO for permission to use their photographs as shown herein.

INTRODUCTION AND SUMMARY

A problem was uncovered during a series of tests on the SRB instrumentation islands in AEDC Tunnel C on 13 January 1979. The white protective paint or the "Turco" coating on the TPS panels began to flow soon after the panels were exposed to the flow. This presented a serious problem especially since the critical pressure sensing, parachute opening baroswitches located on the frustum of the SRB were most likely to be contaminated by the paint flowing down the sides of the SRB nose cone. Because the first two flight articles were already completed, it was necessary to find a solution to the existing paint problem.

(NASA-CR-170884) SPACE SHUTTLE SRB TPS
PROTECTIVE PAINT TEST AND EVALUATION IN NASA
HOT GAS FACILITY AND AEDC TUNNEL C (Lockheed
Missiles and Space Co.) 25 p HC 1.2/HP AC1

N85-35294

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The paint in question is the new white "Turco T6109" which has a light colored resin and an ultraviolet stabilizer as opposed to an "old" Turco used previously on other TPS materials development and evaluation tests. An attempt was made to solve the existing problem by spraying the "old" Turco over the "new" since at the time: (1) it was not known how to remove the "new" Turco sprayed on the TPS and (2) the "old" Turco was believed not to run. This attempt proved futile during the first series of eight tests run on 6 March 1979 in AEDC Tunnel C. It was found from these tests that the "old" Turco also flowed on top of the "new" much the same way as the "new" by itself.

After several meetings and deliberations of all concerned, there appeared to be only two alternatives available — to find a way to remove the bad coating from the existing flight articles on the assembly line, or to remove the entire TPS with it and refurbish them, an expensive proposition. Besides, from the tests conducted so far it could not be determined how far the paint would flow before it froze and the TPS charring process began, nor could it be determined whether enough of it would flow to clog up the baro-switch ports. In view of this and other uncertainties involved and the fact that a great degree of confidence was needed for a critical function such as the opening of the parachutes during the SRB trajectory necessitated the use of a protective paint that would not run. To this effect the personnel of the NASA-MSFC Materials and Processing Lab made up several panels with five possible candidate paints to be tested again at AEDC on 2 April 1979. These coatings were Hypalon; Woolsey; Dow Corning silicone latex (X3-5103); an exterior acrylic latex; and Flame Master (FL77) coating. During this entry in Tunnel C, it was decided to run a trajectory heating profile for the worst heat load location on the SRB forward frustum area. It was believed that the low heating rates during the initial portion of the flight trajectory might lend itself to giving the coatings under test an initial cure that might tend to "bake" them and prevent them from "running" when going through the peak \dot{q} pulse.

It was found that all the coatings, except the Hypalon, had similar undesirable flow characteristics. Also even the Hypalon, which did not flow, would bubble up and disintegrate when it was applied on top of the "new" Turco.

So, at this point, though a new possible paint candidate had been found the fears of solving the old problem of Turco on completed SRB flight articles still existed. Also further tests were necessary to verify the Hypalon and continue the search for a better paint. The NASA-MSFC Hot Gas Facility was utilized for this with two windows added to it to provide camera coverage. No new conclusions were drawn from these tests.

In the meantime, the Materials and Processing Lab of NASA-MSFC found a possible way to remove the Turco coating from the MSA TPS. They succeeded by adding several coats of the same Turco on top of the coating to be removed, and then after cure, etc., peeling all of the paint from the TPS. This method proved quite effective in removing most of the initial coat of paint from the TPS. This process was applied to two MSA panels which were then sprayed with the new candidate paint Hypalon and tested in the Hot Gas Facility. The paint, as expected, did not flow and the TPS performed adequately.

Recently, the Turco coating was removed from an MSA-1 panel by dissolving the paint with a certain agent. This was done in two ways, by dissolving and removing almost all of the paint on one side of the panel and dissolving and removing about 50% of the paint on the other. The panel was then coated with Hypalon and tested as before in the Hot Gas Facility. No evidence of any paint flow nor any adverse performance of MSA was observed.

TECHNICAL DISCUSSION

Descriptions of Test Facilities and Test Conditions: Descriptions of the AEDC Tunnel C Mach 10 and NASA-MSFC Hot Gas Test Facilities and Test Fixtures are given in detail in Ref. 1. Also the local environments and calibrations are presented in Ref. 1.

Description of the Test Panels: Twenty-three panels, some sheet cork (P-50), some B-Stage cork and some MSA panels were run for the paint tests in AEDC Tunnel C. All samples were made on 1/8 in. aluminum substrate and were 11.69 by 15.88 in. in size with the larger side perpendicular to the flow. A sketch of the test panel with the paint pattern on it is shown in Fig. 1.

Figure 2 shows the paint pattern on the test panel used in the Hot Gas Facility. These panels were also made on 1/8 in. aluminum substrate and were 21.46 by 27.65 in. in size.

The test panels were prepared by the MSFC Materials and Processing Lab and machine shops of the MSFC Test Lab.

Test Procedures: The test procedure as far as tunnel operations, model mounting and test monitoring were much the same as in previous SRB TPS tests in both the AEDC Tunnel C and the Hot Gas Facility. These are outlined in Ref. 1.

During the first entry in AEDC Tunnel C for paint tests, the tests were planned to be run at constant heating rate levels to obtain a fixed heat load for the Body Point 1050 which is the maximum heat load point on the SRB frustum. As the tests were being conducted, one panel with Hypalon on one half and "old" Turco on other was inadvertently tested at a lower angle of attack imparting to it a lower \dot{q} level (see group 6-7 of Run Log of Table 1) when this happened and the paint was seen not to flow, it was agreed to run a trajectory type heating rate profile as close as possible to the ascent \dot{q} characteristic for the body point in future tests. It was believed that the lower initial heating rate might have helped cure or "bake" the paint on the TPS and prevented it from running. The actual ascent \dot{q} profile together with the profile that could be attained in Tunnel C to obtain a simulation is shown in Fig. 3.

The duration of the tests in AEDC were determined on-site. The samples were withdrawn from the flow as soon as the paint melted and began to run down the unpainted portion of the test panel. In cases when the paint did not run, the panel was subjected to the full heat load of ascent and reentry. This was done by retracting the panel after ascent simulation, holding the panel in the airlock beneath the tunnel for 150 sec for cooldown and re-inserting it a maximum available heating level for a period equivalent to re-entry heat load.

In the Hot Gas Facility, since visual monitoring of tests could not be done, the samples were run for a fixed duration of 20 sec to observe the paint flow problem, and 43.1 sec to obtain the necessary heat load to check out the TPS affected by paint removal. A complete test log is given in Table 2.

Data Obtained: The data obtained were purely qualitative. The main items of interest were the 16 mm color movies of the samples with a view normal to the surface and pretest and post-test color still photographs of the TPS specimens. Panel substrate temperatures were obtained on HGF panels run to evaluate the TPS after Turco removal and subsequent Hypalon coating. Typical pretest and post test pictures of test panels in AEDC and HGF are shown in Figs. 4 through 11. The photographic results of the other tests are not included here but are on file with the author and with Mr. W. P. Baker, EP44 the NASA-MSFC contract coordinator.

RESULTS AND CONCLUSIONS

- The "old" as well as the "new" Turco paint both flowed about the same time although the "new" flowed first and was followed by the "old."
- An overcoat of "old" Turco on top of the "new" did not prevent nor retard any flow of paint.
- The Hypalon paint stayed on well. It formed small bubbles but did not flow during the entire heat load trajectory.
- All the new coatings, namely, the Woolsey, X3-5103, FL77, exterior latex and also Hypalon when used to overcoat the "new" Turco performed very poorly. They either flowed, bubbled up or disintegrated exposing the "new" Turco underneath which subsequently flowed. The coatings were not successful in even retarding the problem of paint flow.
- There was no effect of the type of TPS material whether MSA, P-50 cork or B-Stage cork on the performance of the paint. The behavior of the paint was independent from the type of TPS under it.

- The MSA panels which were subjected to paint removal either by the process of peeling or dissolving the paint, performed well as far as the rate of recession of the TPS and the rise in back face temperatures was concerned.



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Approved:



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Contract NAS8-32982



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Attach: (1) Table 1
(2) Figs. 1 through 5

REFERENCE

1. Karu, Z. S., and W. G. Dean, "SRB Materials Test and Evaluation in NASA-MSFC Hot Gas Facility, NASA-Ames 3.5 Foot HWT and AEDC Tunnel C," LMSC-HREC TM D497497, Lockheed Missiles & Space Company, Huntsville, Ala., November 1977.

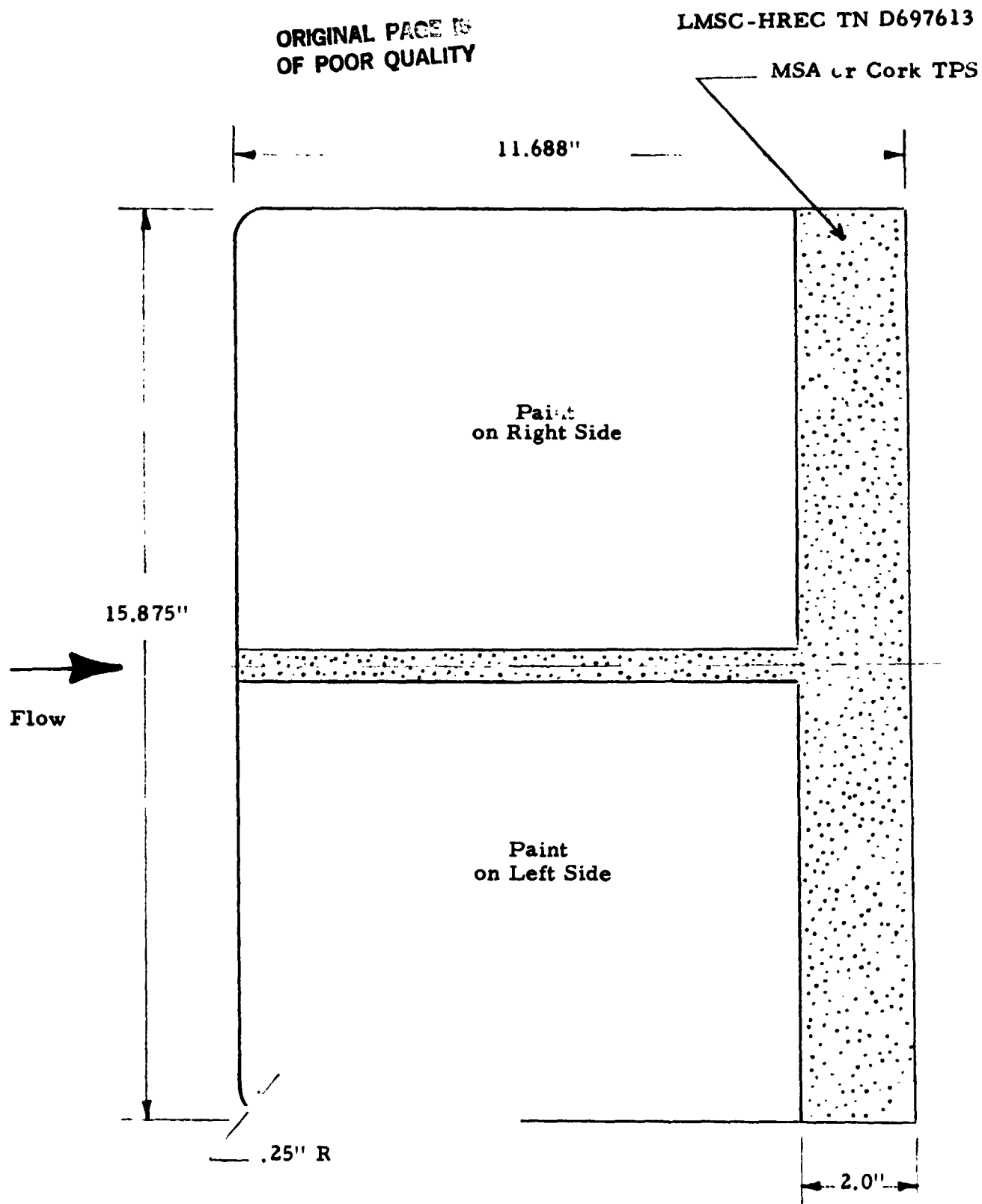


Fig. 1 - The Test Panel Used at AEDC Showing the Pattern in Which the Paints Were Sprayed on the TPS

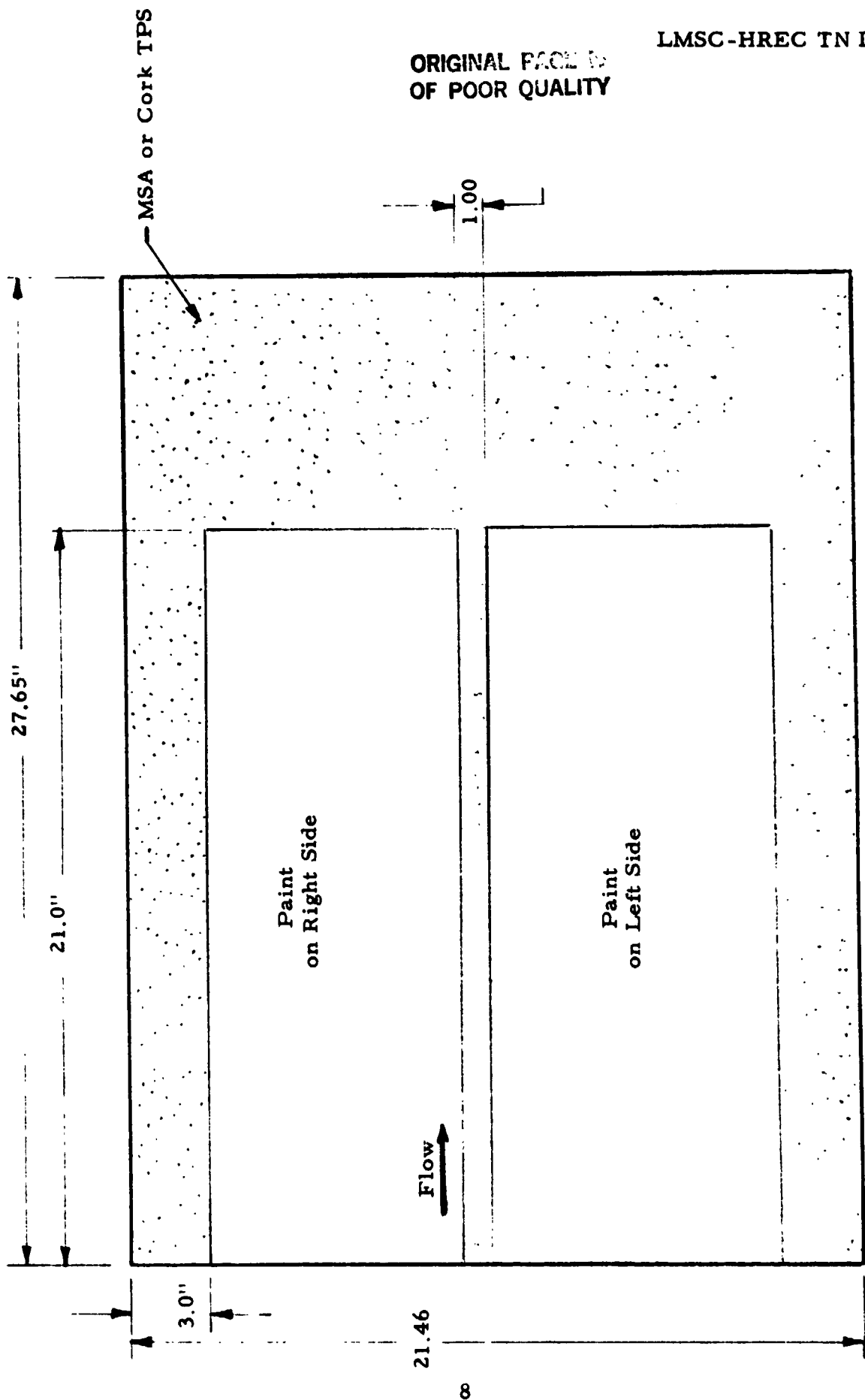


Fig. 2 - The Test Panel Used at the Hot-Gas Facility Showing the Paint Pattern on the TPS

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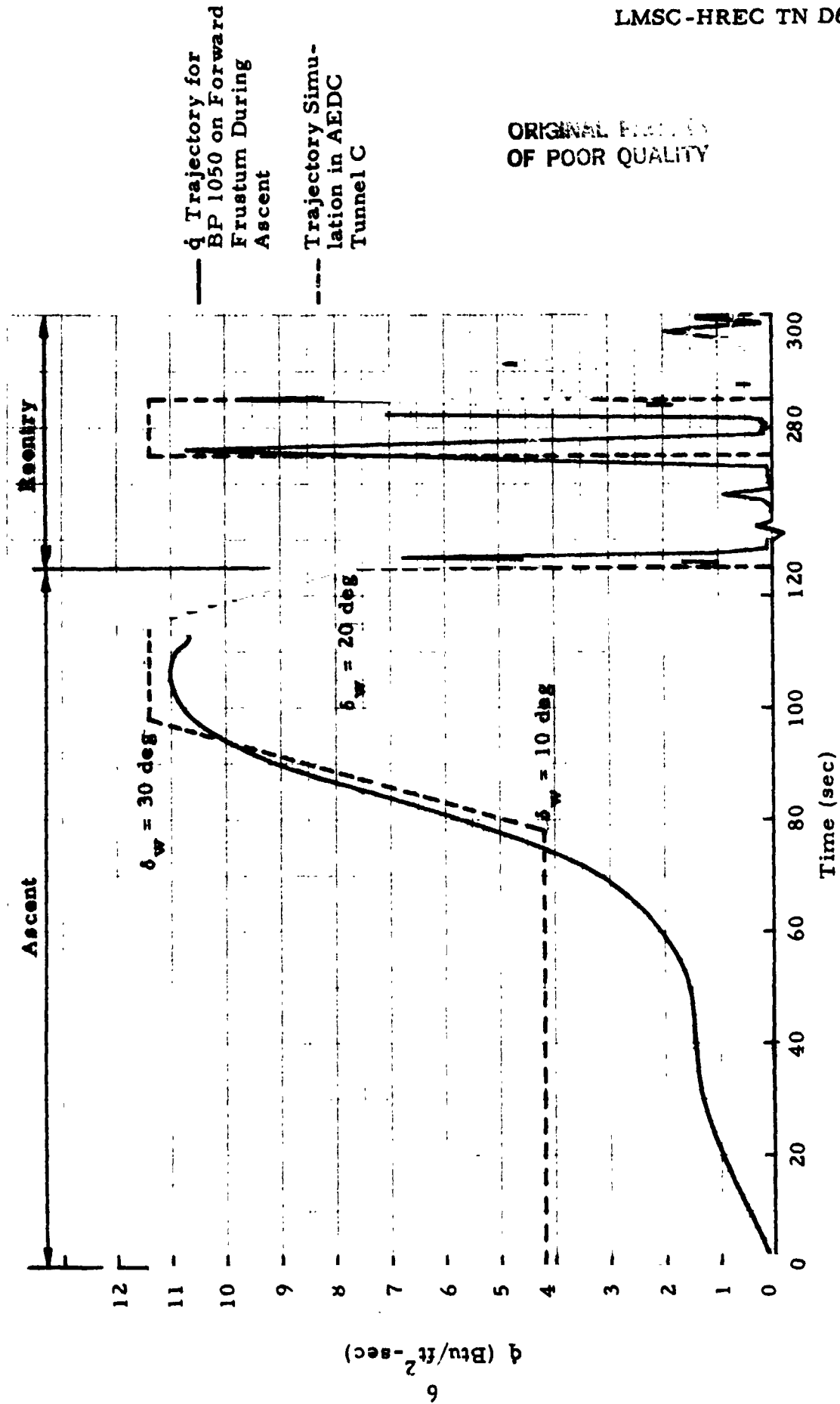


Fig. 3 - Actual Heating Rate Profile for Maximum Heat Load Location on SRB Frustum and its Simulation in AEDC Tunnel C

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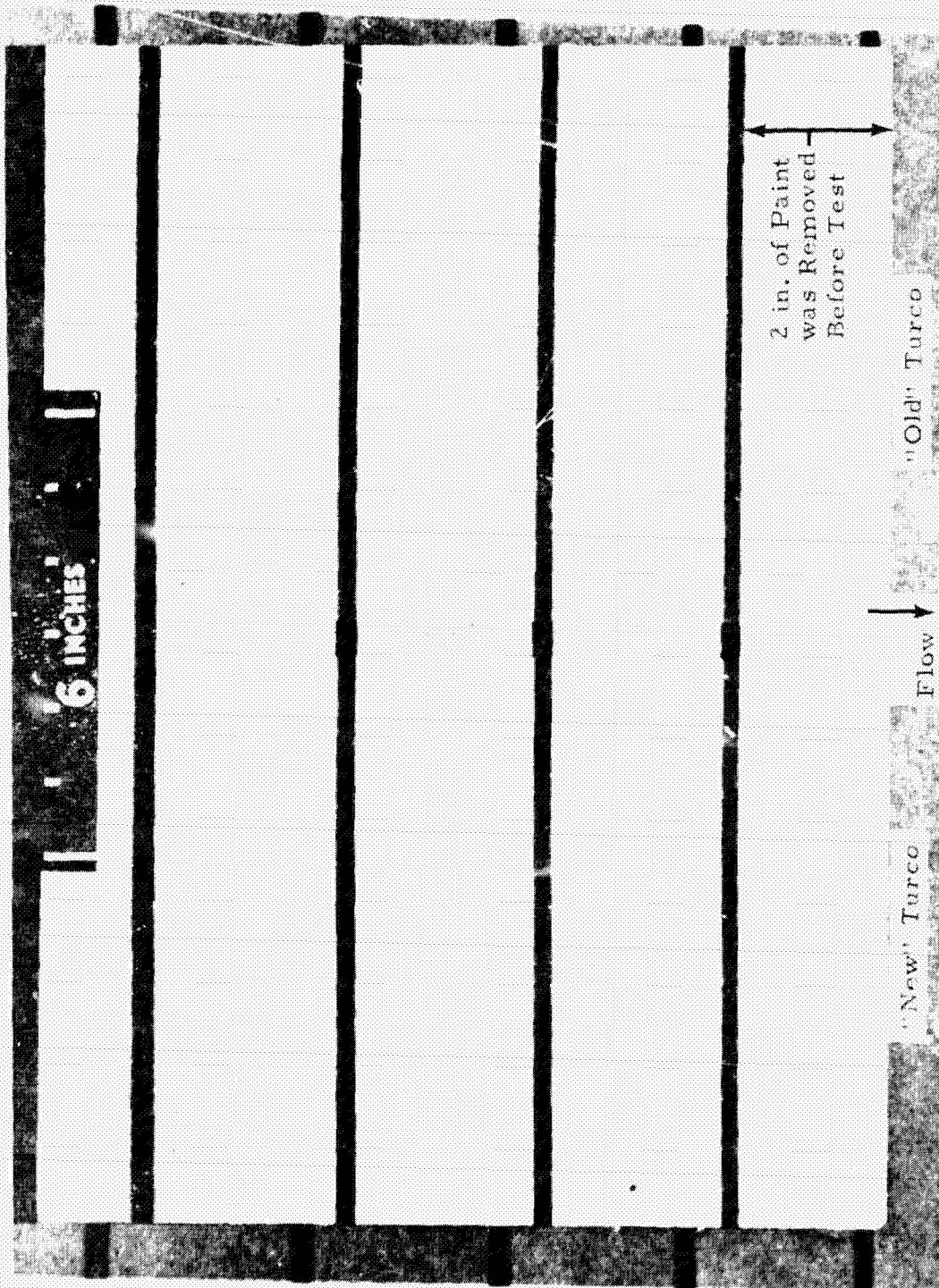


Fig. 4a - Pretest Photograph of Paint with Two Types of Turco Paint on B-Stage
Cork (Panel BVP-15)

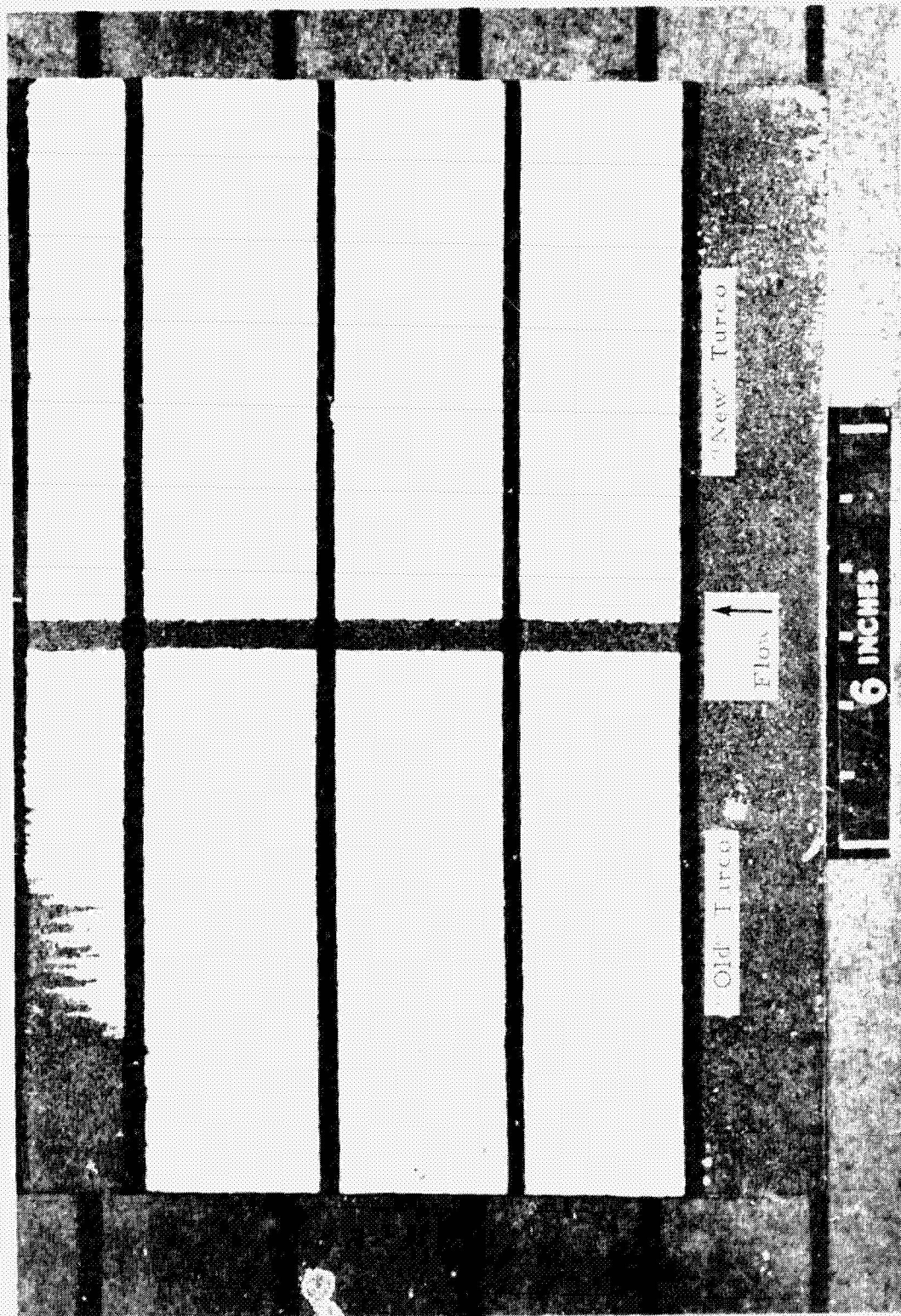


Fig. 4b - Post-Test Photograph Showing the "New" Turco Having Completed Its Run
Down the Panel Ahead of the "Old" Turco



Fig. 5a - Pretest Photograph of Paint Panel with Hypalon Paint Applied over "New Turco" on One Side (Panel C-3)

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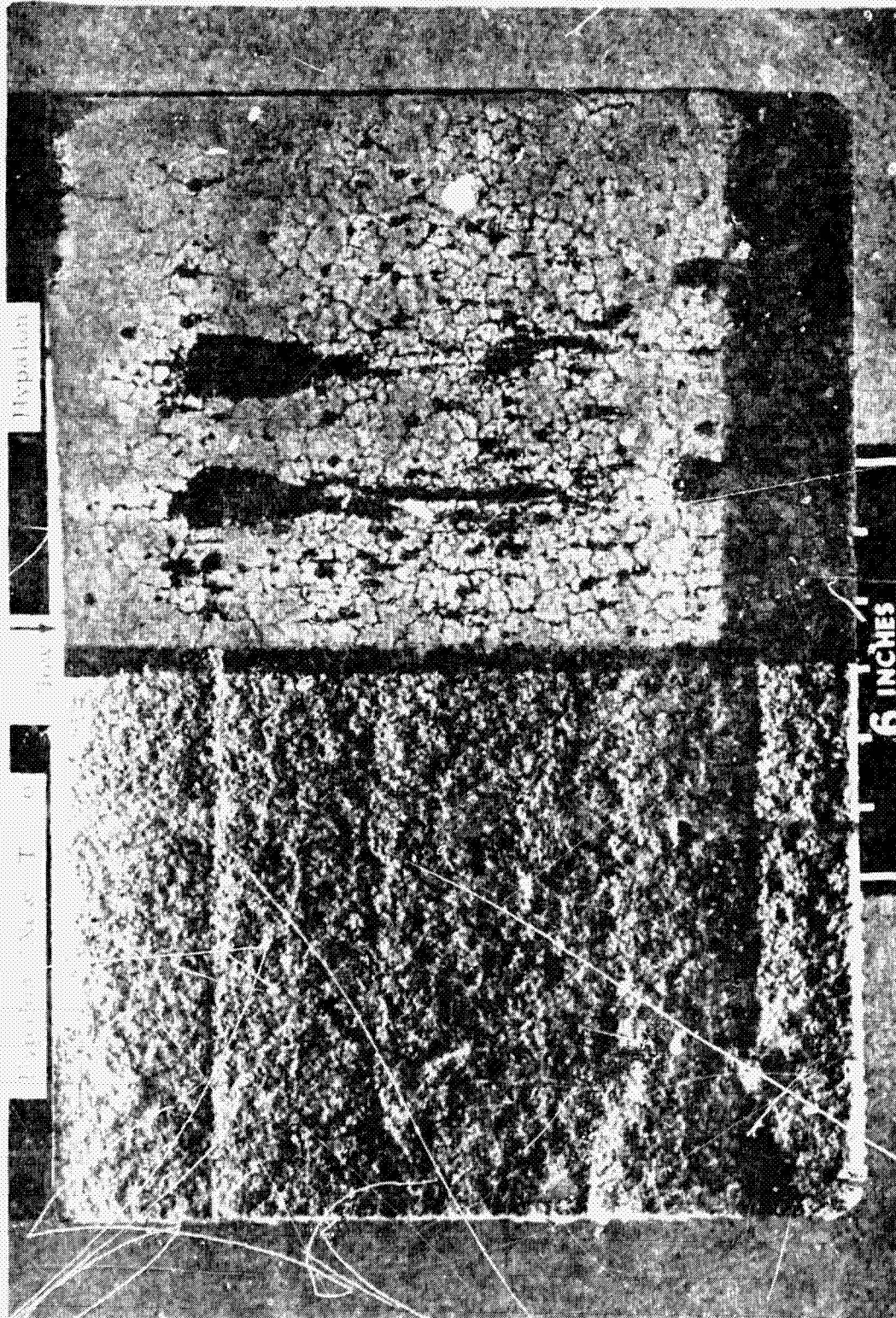


Fig. 5b - Post-Test Photograph. Showing the Hypalon by Itself, though "Cracked" Up and Having "Popcorned," Has Not Flowed Whereas when Coated over "New" Turco Has Not Prevented the Problem of Faint Flow

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Fig. 6a - Pretest Photograph of Two Paints Coated over "New" Turco on P-50 Cork
TPS (Panel C-7)

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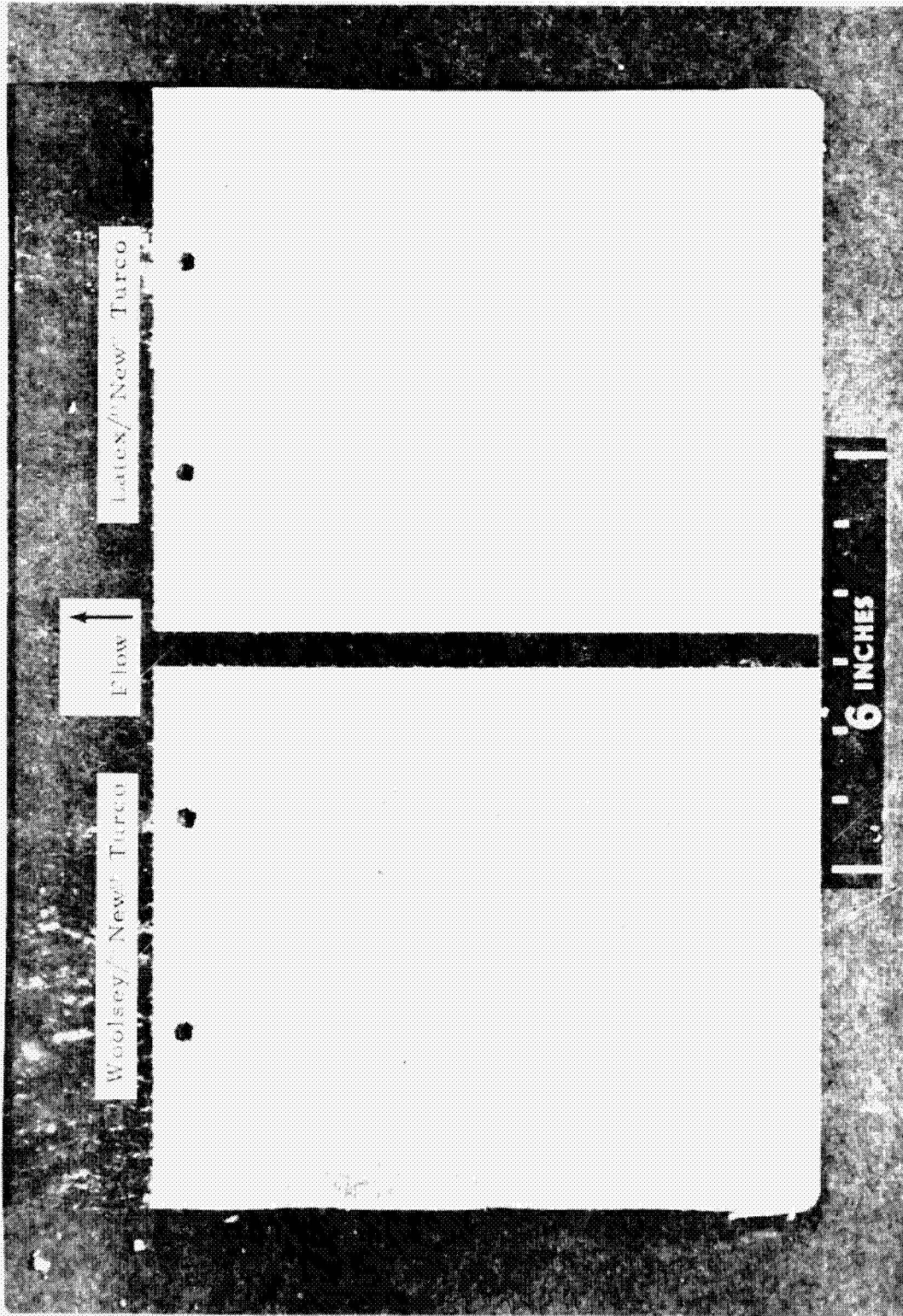


Fig. 6b - Post-Test Photograph Showing the Woolsey Coating Having Disintegrated Causing Paint Debris. (The Panel Was Run for Only 73.6 sec. If Run Longer the "New" Turco Would Have Run.)

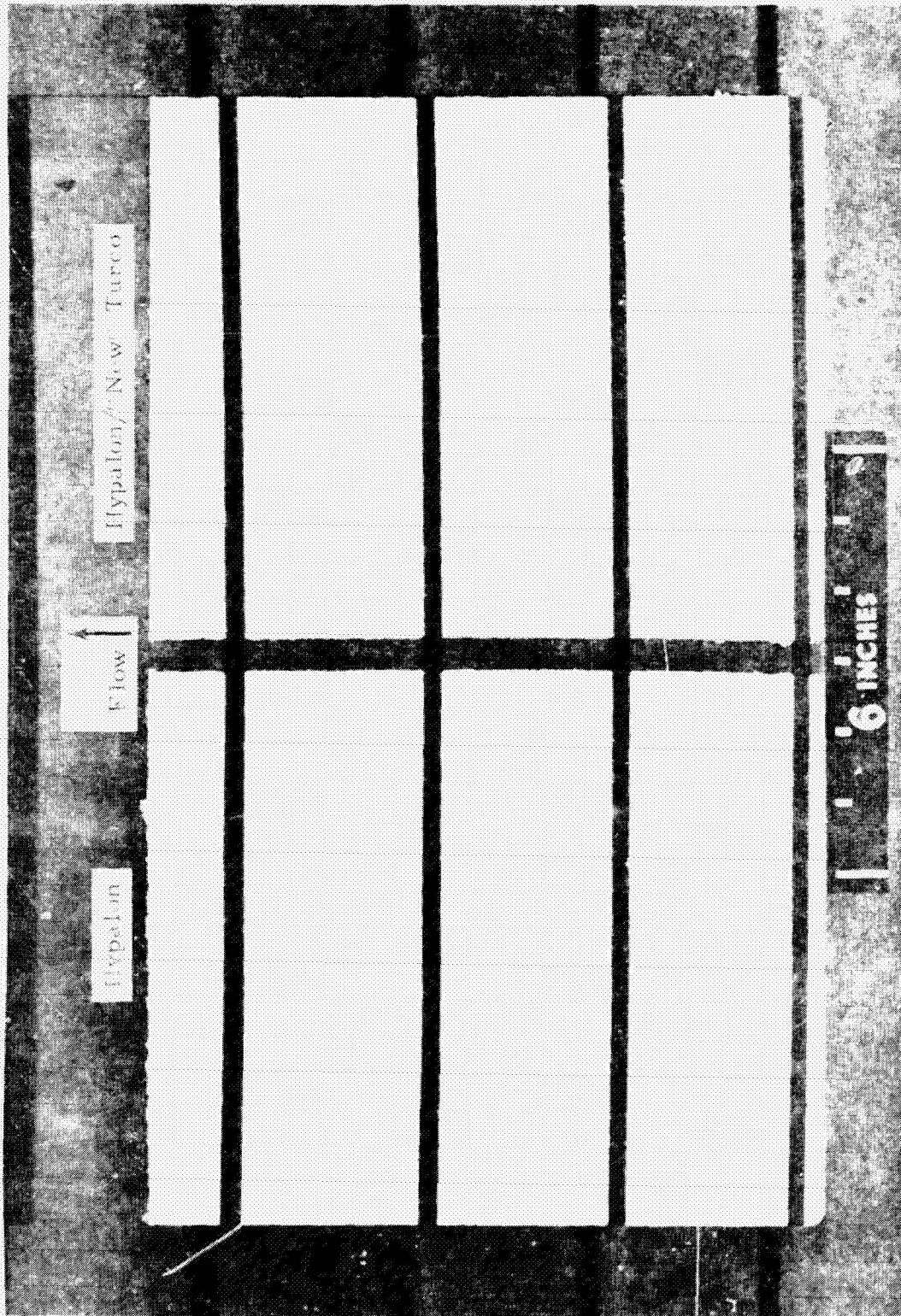


Fig. 7a - Pretest Photograph of Hypalon Paint and an Overcoat of the Same on "New" Turco
on MSA TPS (Panel M-2)

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Fig. 7b - Post-Test Photograph Showing Evidence of "New" Turco Paint Flow After Overcoat of Hypalon Was Lost on One Side And Bubbling and "Popcorning" Behavior of Hypalon on MSA on the Other Side (Compare with Fig. 5b)

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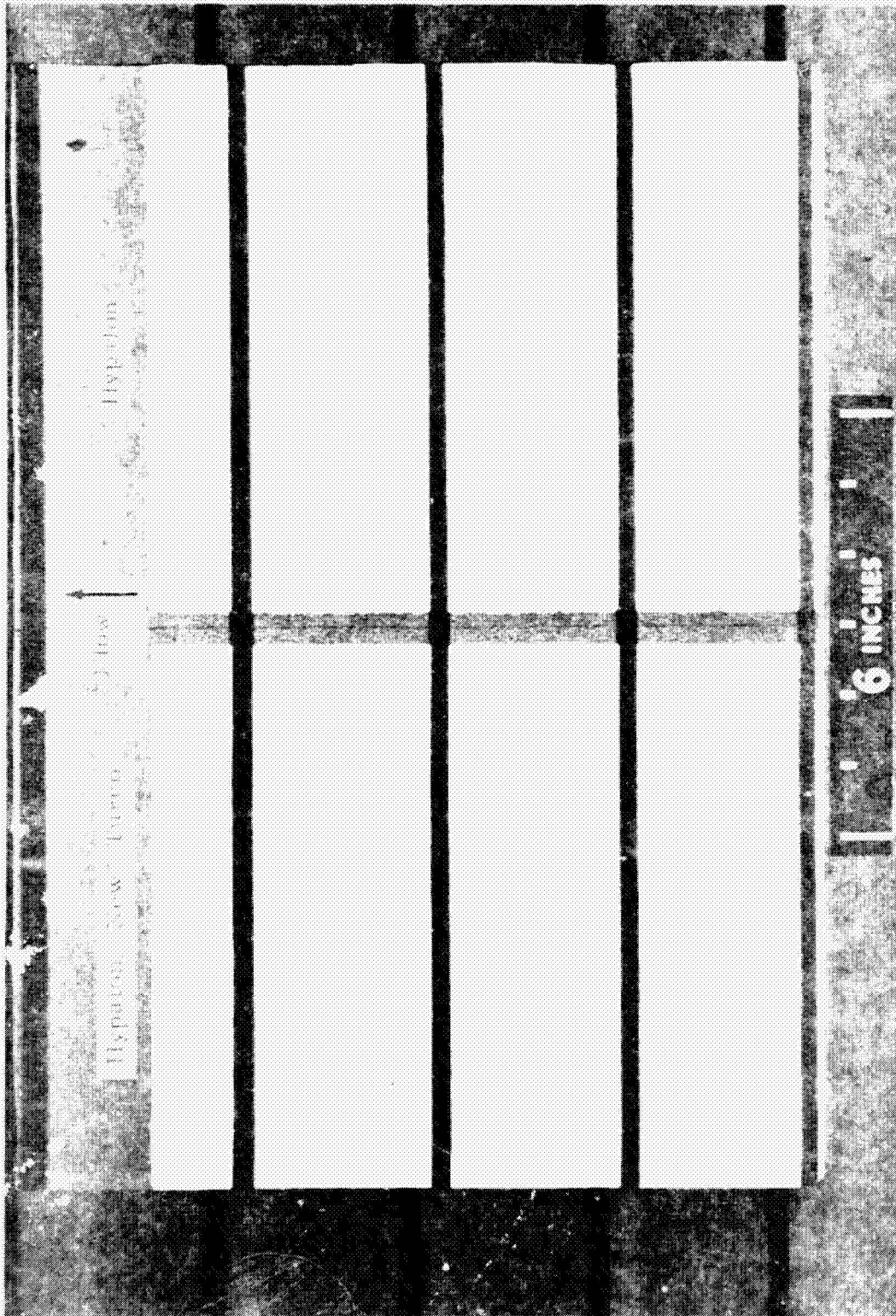


Fig. 8a - Pretest Photograph of Hypalon Paint and an Overcoat of the Same on "New" Turco
on P-50 Cork TPS (Panel C-6)

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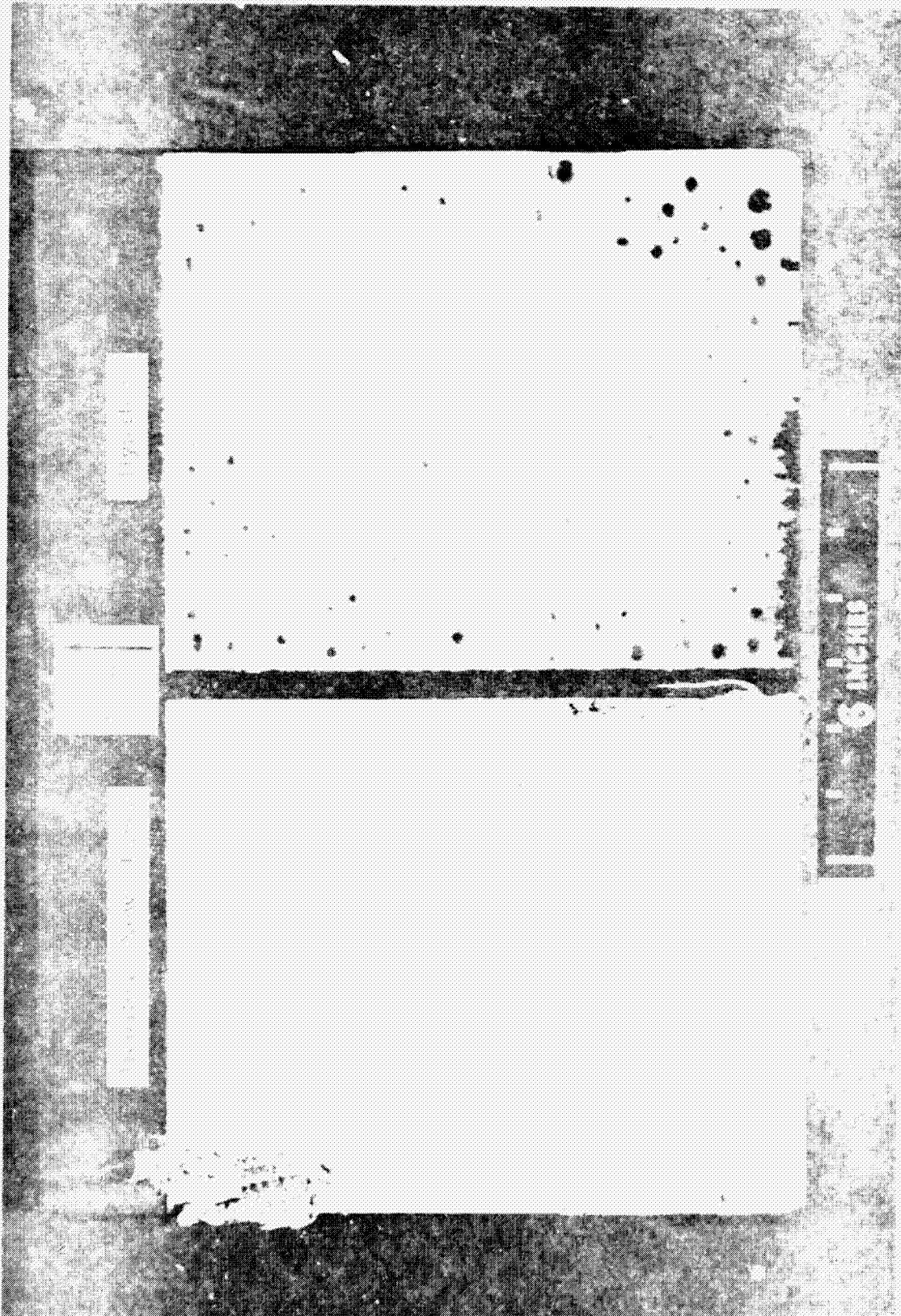


Fig. 8b - Post-Test Photograph of a Short Duration (37.3 sec) Run Showing the Performance of Hypalon on "New" Turco and Hypalon by Itself (Compare with Fig. 5b)

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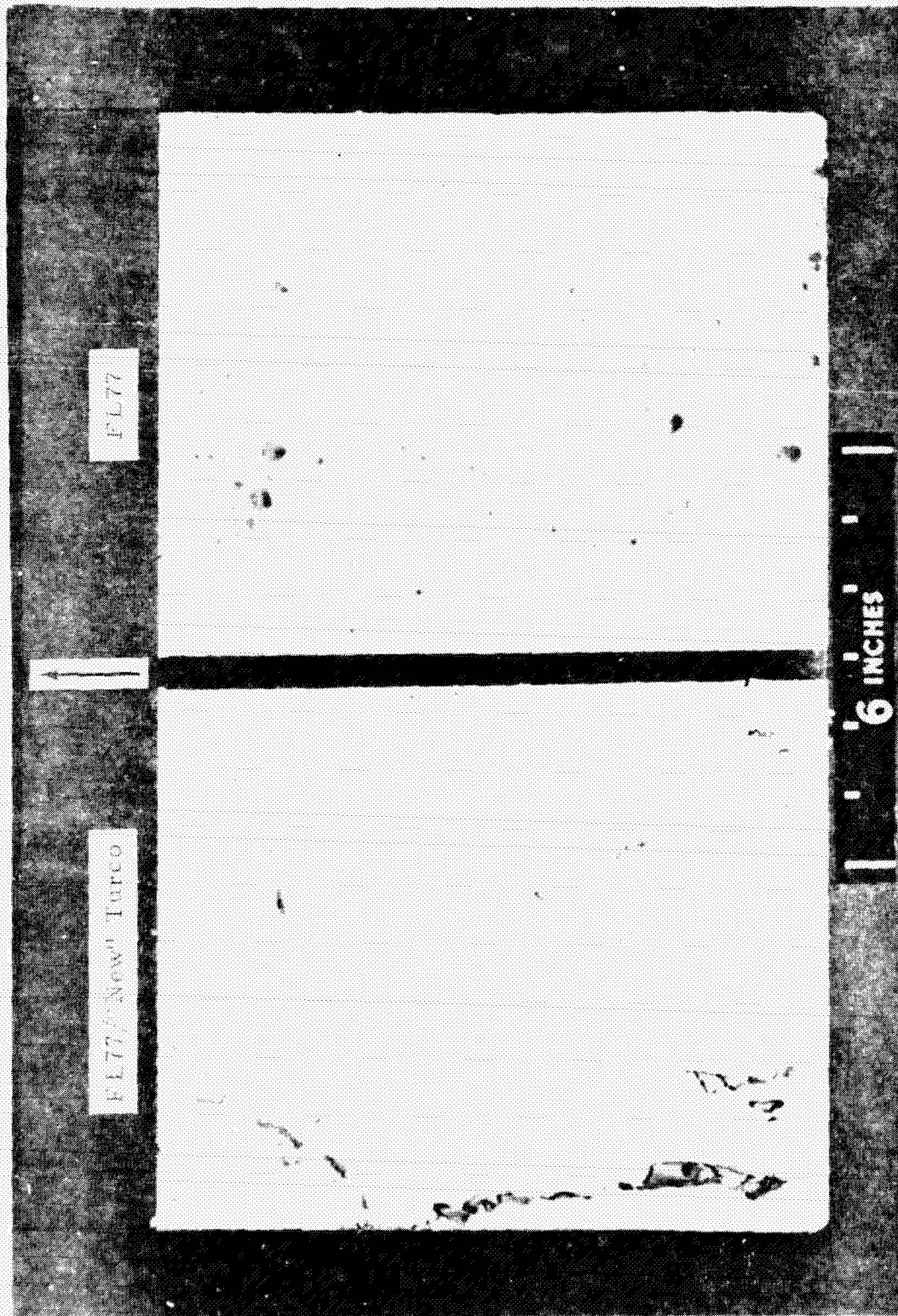


Fig. 9 - Post-Test Photograph of Paint Panel with FL77 Coating and FL77 over "New" Turco
Showing the Problem of Peeling of FL77 over the "New" Turco (Panel C-14)

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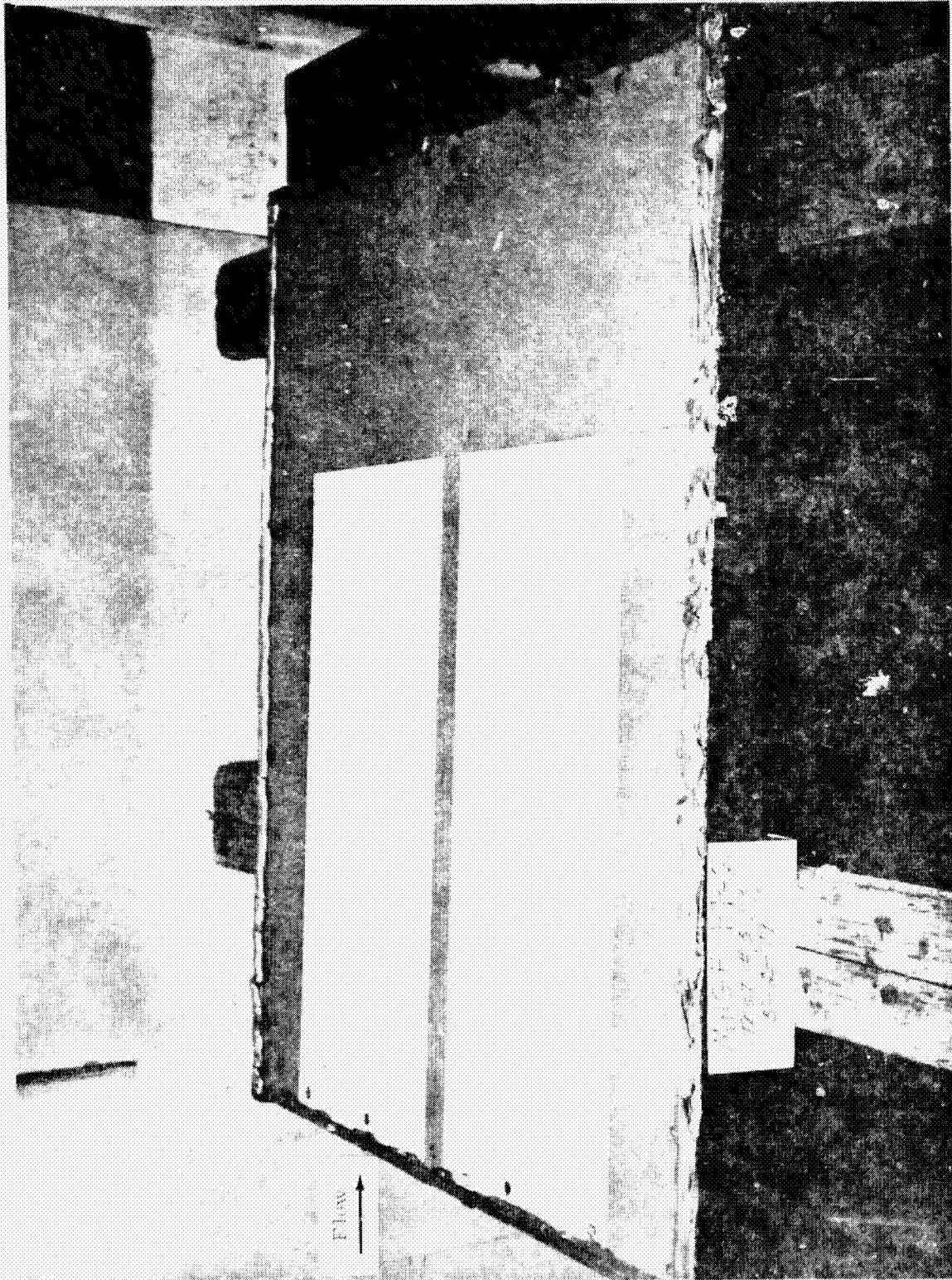


Fig. 10a - Pretest Photograph of Hot Gas Facility Paint Test Panel with Hypalon on P-50 Cork

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Fig. 10b - Post-Test Photograph of Hypalon Paint Panel Showing No Flow of the Paint

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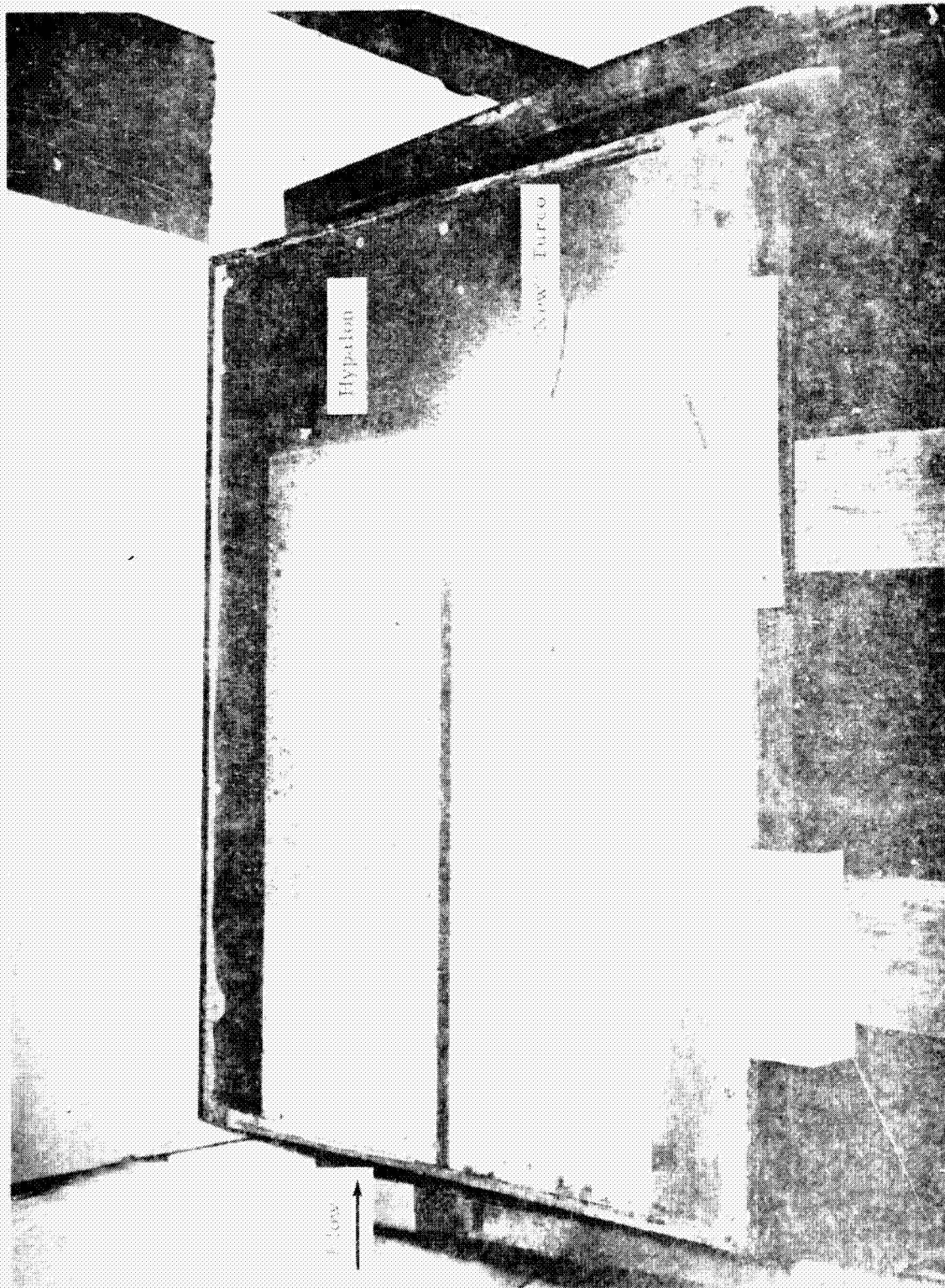


Fig. 11 - Post-Test Photograph of Hot Gas Facility Paint Panel with Hypalon on One Side and "New" Turco on the Other (The "New" Turco is seen to have melted and flowed whereas the Hypalon has not.)

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Table 1
RUN LOG AND TEST CONDITIONS FOR SRB PAINT TESTS IN AEDC TUNNEL C

Date	Group No.	Panel No.	Panel Description			Wedge Angle δ_w (deg)	Average \dot{q} Level (Btu/ft ² -sec)	Run Time θ (sec)
			Paint		TPS			
			Right Side	Left Side				
3-7-79 ↓	1	OPS-4B	T _n	T _o	1/8 MSA	27.5	11.3	14.3
	2	OPS-4A	T _n	T _o /T _n	1/8 MSA	18.5	7.6	33.3
	3	BVP-15	T _o	T _n	3/8 B-cork	20.0	8.0	30.8
	4	BVP-18	T _n	T _o /T _n	1/2 B-cork	20.0	8.0	32.5
	5	BVP-16	T _o	T _n	3/8 B-cork	25.0	10.4	21.0
	6	BVP-9	Hyp	T _o	1/4 B-cork	15.0	6.4	102.7
	7	BVP-9	Hyp	T _o	1/4 B-cork	30.0	11.5	36.8
	8	BVP-20	T _o /T _n	T _n	1/2 B-cork	10 for 60 sec 15 to 80 sec 30 to 123 sec	4.2 6.4 11.5	123.1
4-2-79 ↓	60	C-1	T _n	T _o	1/4 P-50 cork	Trajectory - See Fig. 3		68.0*
	61	M-1	T _n	T _o	1/4 MSA	↓	↓	127.0
	62	C-3	Hyp	Hyp/T _n	1/4 P-50 cork			147.0 + 150.0 + 15.9
	63	C-4	Hyp	Hyp/T _n	3/8 P-50 cork	30.0	11.5	66.9
	64	C-7	Wool/T _n	Latex/T _n	1/4 P-50 cork	Trajectory - See Fig. 3		73.6
	65	C-11	X3-5103/T _n	FRL/T _n	1/4 P-50 cork	↓	↓	137.8
	66	M-2	Hyp	Hyp/T _n	1/4 MSA			136.6 + 150.0 + 14.9
	67	M-4	Wool/T _n	Latex/T _n	1/4 MSA			96.8
	68	M-6	X3-5103/T _n	FRL/T _n	1/8 MSA			98.4
	69	C-2	T _o	T _n	1/4 P-50 cork			131.7 + 150.0 + 14.0
	70	C-5	Hyp/T _n	Hyp	3/8 P-50 cork			134.3 + 150.0 + 13.5
	71	C-6	Hyp/T _n	Hyp	1/4 P-50 cork			37.3
	72	C-13	FL77	FL77/T _n	1/4 P-50 cork			133.4 + 150.0 + 13.4
	73	C-14	FL77/T _n	FL77	1/4 P-50 cork			38.6
	74	M-7	FL77	FL77/T _n	1/4 MSA			144.1 + 150.0 + 13.4
	78	M-3	Hyp/T _n	Hyp	1/8 MSA	30.0	11.5	67.3

Notes:P_o = 1800 psiaT_o = 1900 R

Mach No. = 10

Groups 1 and 2 panels mounted in recessed area of sharp edged wedge; remaining panels mounted in water-cooled adapter (in 0 deg ramp condition). See Ref. 1 for mounting details.

Abbreviations:T_n - "New Turco

Wool - Woolsey

T_o - "Old" Turco

X3-5103 - Dow Corning silicone latex

Hyp - Hypalon

Latex - Exterior acrylic latex

FL77 - Flame Master

* Some trajectory runs were not completed since the panel was retracted after paint started to flow.

Table 2

Abbreviations
T_n - "New" Turco
T₃ - Another Version of Turco with
 a New Phenolic Resin
Hyp - Hypalon Paint
FL77 - Flame Master Paint

$$\dot{q} \text{ range} = 12.5 - 8.2 \text{ Btu/ft}^2\text{-sec (see Ref. 1)}$$